NASA Advisory Council Aeronautics Committee Report

Ms. Marion Blakey
Chair
NASA Headquarters
November 30th, 2016

Aeronautics Committee Membership

- Ms. Marion Blakey, Chair, *Rolls Royce North America*
- Mr. John Borghese, Vice Chair, *Rockwell Collins*
- Dr. Missy Cummings, *Duke University*
- Dr. John Paul Clarke, *Georgia Institute of Technology*
- Dr. Michael Francis, *United Technologies*
- Dr. Greg Hyslop, *The Boeing Company*
- Dr. Lui Sha, *University of Illinois*
- Dr. Karen Thole, *Pennsylvania State University*
- Dr. David Vos

Areas of Interest Explored at Current Meeting

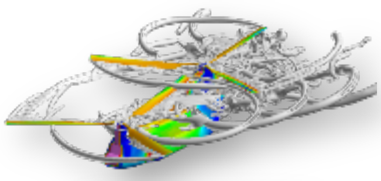
Topics covered at the Aeronautics Committee Meeting held on November 14-15, 2016 at Ames Research Center, Moffett Field, CA:

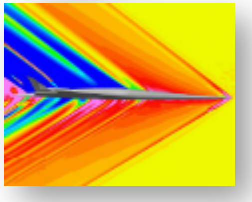
- CFD Vision 2030 Implementation Plan*
- New Funding Model for Key Facilities*
- Vision & Strategic Planning for Advanced Aviation Operations (Thrusts 1, 5 & 6)
- Real Time System Wide Safety Roadmap and Project Planning
- Autonomy Roadmap and Project Planning*

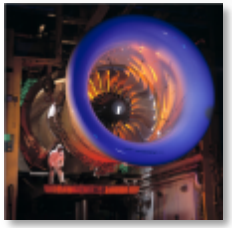
* These topics have related findings provided by the Aeronautics Committee

Vision of CFD in 2030

- **Emphasis on physics-based, predictive modeling**
  Transition, turbulence, separation, chemically-reacting flows, radiation, heat transfer, and constitutive models, among others.
- **Management of errors and uncertainties**
  From physical modeling, mesh, natural variability, lack of knowledge in the parameters of a particular fluid flow problem, etc.
- **A much higher degree of automation in all steps of the analysis process**
  Geometry creation, meshing, large databases of simulation results, extraction and understanding of the vast amounts of information generated with minimal user intervention.
- **Ability to effectively utilize massively parallel HPC architectures that will be available in the 2030 time frame**
  Multiple memory hierarchies, latencies, bandwidths, etc.
- **Flexible use of HPC systems**
  Capacity- and capability-computing tasks in both industrial and research environments.
- **Seamless integration with multi-disciplinary analyses**
  High fidelity CFD tools, interfaces, coupling approaches, etc.





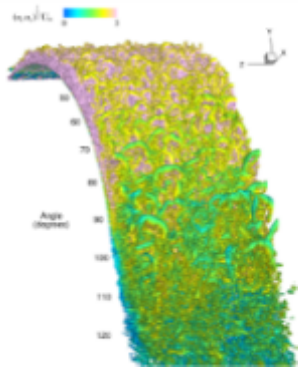


Predictive and automated physics-based tools required for timely analysis/design of novel configurations.

Implementation Plan, Going Forward

- **Review/update roadmap every 5 years**
  - Current TTT priorities encapsulated in the 3 TCs (technical challenges) presented earlier
  - Review progress and adjust research portfolio periodically to maximize impact on vision 2030 objectives
- **Explore collaborative opportunities with OGAs, more aggressively**
  - Order of magnitude more DOD and DOE investment in HPC
- **Leverage CFD community activities through AIAA**
  - Focused workshops, special sessions
- **Seek opportunities to interact with international experts**
  - European institutions leading in certain areas
- **Re-evaluate use of CCEs when additional funds are available**
  - First Priorities: (1) Geometry and Grid Generation, (2) HPC and Knowledge Extraction
  - Roughly $4M/year commitment for 5 years, not in the current budget
- **Consider use of prizes and challenges**

CFD Vision 2030 - Summary



- Exciting suite of **fundamental, cross-cutting research**
- Developing and validating **critical computational models and tools** for application to NASA projects and the broader aeronautics community
- Leveraging **external expertise** to augment and complement in-house research efforts via NRAs

- Full implementation of the vision will be enabled by passage of President's FY17 budget
- Focus on **collaborations** with DOD and DOE to make progress in the currently *un-funded* roadmap swim lanes
  - HPC
  - Geometry and Grid Generation
  - Knowledge Extraction

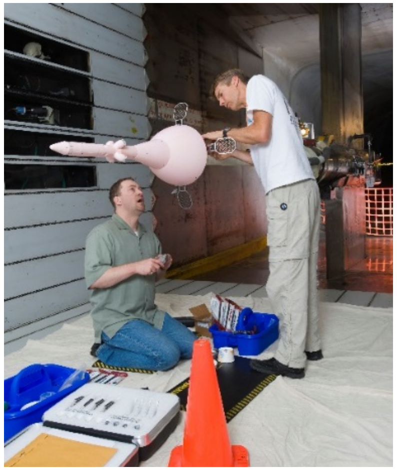
Analysis and Design of New Aerospace Configurations

Committee Observation for ARMD AA on CFD 2030 Plan

The Committee understands the importance of Computational Fluid Dynamics(CFD) has played in the development of efficient aerodynamics for airplane structures and turbine engine development. The CFD project has good project planning. Given the length of this project, the Committee suggests that the project define the current state of the art, what specific problems are being solved, gaps to solve these problems and develop clearly defined milestones on a frequent basis to measure progress throughout the project.

New Funding Model for Key Facilities

Vision for the NASA's Aerosciences Ground Test Funding Model



One of the first NASA Capability Management recommendations was a **New Funding Model for Aerosciences ground test capabilities**.

In **FY17** the New Funding Model will fully cover the operational cost for NASA users of a key set of critical aeroscience ground test facilities. In addition, limited funds are available for capability advancements, new test technologies, and maintenance.

Starting in **FY19** consumables (e.g. power, fuel, etc.) will also be covered.

The primary objective of the New Funding Model is to improve access to our facilities, putting them back in the hands of our researchers and engineers to execute NASA's missions, programs, and projects. The New Funding Model will:

- **Enable technology innovation and risk reduction by providing easier access and remove cost bias that favors computation over test**
- **Reinforce the role of facilities as a NASA centrally managed resource**
- **Improve facility utilization**
- **Enable capability and discipline sustainability**
- **Provide an improved measure for facility decisions involving capability partnering, investment, and divestment**

The NASA **Aeronautics Evaluation and Test Capability (AETC) Project** will manage the aeroscience ground test capability portfolio for the Agency under this New Funding Model.

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Aeronautics Evaluation and Test Capabilities (AETC) Project

"…Improve access to our facilities, putting them back in the hands of our researchers and engineers to execute the NASA missions, programs, and projects…" **NASA Aerosciences Capability Leadership Team**

Vision

- **Sustain** and **improve test capabilities** and **test technologies** in support of NASA testing requirements - *"The right facility at the right time"*

Scope

- Aeroscience ground test facilities deemed critical to NASA
- Operations, maintenance, and new capability and test technology advancements
- Complementary computing capabilities in conjunction with ground experimentation capabilities

Ames Research Center

Glenn Research Center

Langley Research Center

New Funding Model - Summary

- NASA's New Funding Model started in FY17 and will improve access to our facilities to better execute NASA's missions, programs, and projects.
  - Enable technology innovation and risk reduction by providing easier access and remove cost bias that favors computation over test
  - Reinforce the role of facilities as a NASA centrally managed resource
  - Improve facility utilization
  - Enable capability and discipline sustainability

- The new model also provides increased opportunities to partners from commercial and outside agencies where mutually beneficial interests and data sharing are present.

- Additional information on the new model, testing at NASA and/or partnership opportunities can be directed to:

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Committee Observation for ARMD AA on New Funding Model

Wind tunnel testing continues to be an important part of air vehicle and engine development. The cost associated with extensive testing sometimes inhibits facilities use leading to insufficient testing and sometimes a lack of full usage of the tunnels. The Committee agrees with this new approach of funding the non-recurring wind tunnel costs. Given the dynamics of influencing usage using a new cost model, the committee suggests that the results of this new model be evaluated frequently and adjusted if necessary.

Vision & Strategic Planning for Advanced Aviation Operations (Thrusts 1, 5 & 6)

- Brief review of ARMD's Strategic Thrusts (Strategic Implementation Plan)
  - Safe, Efficient Growth in Global Operations
  - Innovation in Commercial Supersonic Aircraft
  - Ultra-Efficient Commercial Vehicles
  - Transition to Low-Carbon Propulsion
  - Real-Time System-Wide Safety Assurance
  - Assured Autonomy for Aviation Transformation
- All Strategic Thrust Roadmaps have been completed and posted
  - https://www.nasa.gov/aeroresearch/strategy
- ARMD has tasked the NRC Aeronautics and Space Engineering Board to perform an indepth study on a National plan for Real-Time System-Wide Safety Assurance (Thrust 5)
  - This is the third study; Transition to Low-Carbon Propulsion (Thrust 4) and Assured Autonomy for Aviation Transformation (Thrust 6) have already been completed.

ARMD Six Strategic Thrusts

Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard

Ultra-Efficient Commercial Vehicles

- Pioneer technologies for big leaps in efficiency and environmental performance

Transition to Low-Carbon Propulsion

- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system

Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications

Strategies for Thrust 5: RSSA

- Leverage growing **sources of aviation data**, commercial data analytics methods, architectures, “internet of things” to enable safety **monitoring, prediction,** and **prognostics capabilities**
- Conduct **fundamental safety research to understand the general or composite properties of and margins for safe operations** across the NAS and enable eventual broad RSSA capabilities
- Expand functionality through **evolutionary development, demonstration** and adoption of capabilities
- Leverage the strengths of **both human and machine agents** to support intelligent, adaptive mitigation strategies for optimum threat management
- Achieve stakeholder trust and consensus through **frequent demonstration of benefits** to ensure access to the rapidly growing body of safety relevant data from FAA, operators, and system providers

Key Dependencies and Strategic Partnerships

- **Data policy and regulation, stakeholder trust**
  - Access to sensitive data requires trust and cooperation of those who own key data sources (airlines, airports, ASIAS)
  - NASA can support trust and buy-in through rigorous assurance evidence and demonstration of benefits
  - **Initiating collaboration with the FAA, and made initial inroads at ASIAS, through System-wide Safety RTT**
  - **Working with individual airlines to access data and demonstrate benefit**
- **Cybersecurity**
  - NASA is addressing some of the data assurance issues but will need to rely on the community effort and progress made by OGA, academia and industry.
  - **Need to establish partnerships**
- **Advances in Machine Learning and Computational Power**
  - Advances in machine learning–cognitive computing to support of automated response planning and execution
  - Leverage the synergy of data analytics, intelligent systems technologies, machine learning, high performance computing and simulation from industry, academia and DoD
  - At least one large industry partner is moving forward with integration and analysis of heterogeneous aircraft data
  - **Have yet to identify partners pushing forward on real-time capability, though it is the logical extension of ongoing work**
- **System-wide Implementation**
  - NASA will roll out assured methodologies and capabilities through individual operators (airlines, airports, ATC facilities)
  - Will rely on industry partners for development of architectures to support integration of capabilities
  - Look to FAA for to support NAS-wide implementation (i.e., ASIAS, ASRS) to support a comprehensive, system-wide capability
  - **ASIAS has achieved success with data sharing**
  - **Must find a way to share, incorporate tools and capabilities**

Updated Outcome Statements

Domain Specific (Real-time) Safety Monitoring and Alerting Tools (2015-2025)

Expanded system awareness through increased access to safety relevant data and initial integration of analysis capabilities; improved safety through initial real-time detection and alerting of hazards at the domain level and decision support for limited, simple operations.

Integrated Predictive Technologies with Domain Level Application (2025-2035)

NAS-wide availability of more fully integrated real-time detection and alerting for enhanced risk assessment and support of initial assured human and machine decision support for mitigation response selection for more complex operations.

Adaptive Real-time Safety Threat Management (2035-2045)

Fully integrated threat detection and assessment that support trusted methods for dynamic, multi-agent planning, evaluation, and execution of real-time risk mitigating response to hazardous events.

ARMD Strategic Thrusts and Roadmaps

- The NASA Aeronautics Research Mission Directorate is producing a set of roadmaps for each of the six Strategic Thrusts set forth in the 2015 NASA Aeronautics Strategic Implementation Plan.
- The roadmaps are intended to represent a community view of the outcomes of NASA research. They will be used to guide project plans and other ARMD activities aimed at fulfilling the Strategic Implementation Plan.

The objective of Strategic Thrust 6 is to enable autonomous systems that employ highly intelligent machines to maximize the benefits of aviation to society.

- NASA Aeronautics Strategic Implementation Plan, 2015

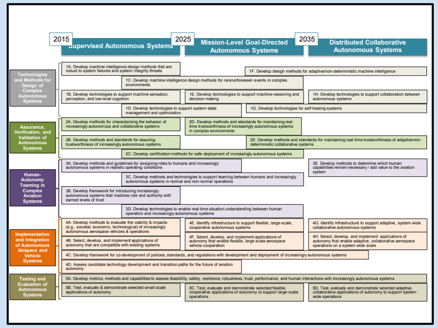
Autonomy is Required to Enable a Long-Term Aviation Vision

- *Anyone can safely fly any time and anywhere…*
- *with high confidence…*
- *in a fraction of the time it takes today…*
- *while sharing the sky with 1,000 times more vehicles than today…*
- *as some of those vehicles accomplish new missions…*
- *in close proximity to people and property…*
- *without harming the environment.*

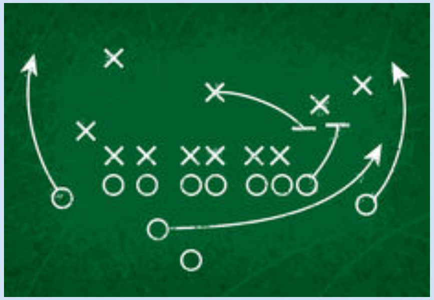
- Autonomy will foster a radical increase in aviation efficiency, reliability, and dependability through system-wide operational planning and highly responsive replanning to changes
- The aviation system will be so large and complex that it would be unmanageable without machine intelligence
- Autonomous machines will achieve unprecedented agility through high-bandwidth sensing, replanning, reconfiguration, and control
- Networked multi-vehicle systems will collaborate to achieve new goals
- Machine intelligence will enable new types of vehicles and missions, unconstrained by the requirements of today's conventional vehicles
- Autonomy will augment human abilities and make some tasks easier for humans, allowing machines to assist us and safely work among us
- Configured by autonomous systems, vehicles will continuously operate at peak performance and efficiency

Roadmap Elements

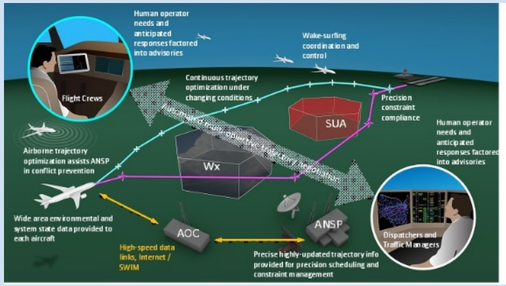
Three parallel and interdependent elements to achieve the Vision



Research Challenges
Technical activities to achieve knowledge breakthroughs and advance aviation autonomy capabilities



Advancement Strategies
Approaches employed by NASA to achieve aviation autonomy objectives



Mission Products
Targeted NASA and community capabilities that facilitate a viable path toward mature and widespread aviation autonomy

Vision

Autonomy Roadmap Summary

- NASA ARMD has developed a roadmap to guide activities for Aeronautics Strategic Thrust 6: Assured Autonomy for Aviation Transformation
  - Major elements of the roadmap are Research Challenges, Advancement Strategies, and Mission Products with outcomes that produce defined capabilities and benefits
  - Due to the game-changing potential and fast-moving nature of autonomous systems, candidate Mission Products are focused primarily on Outcome 1 (2025), with an eye on advancement toward ultimate capabilities
- Execution will rely on collaborative partnerships to strategically leverage efforts and resources
- Autonomous Systems Project is in formulation during FY17; full execution is set to begin in FY18
  - Project planning has identified project goals, initial technical and strategic barriers, R&D work areas, and work selection process

More Information: http://www.aeronautics.nasa.gov/strategic-plan.htm

Committee Recommendation for ARMD AA on the Assured Autonomy for Aviation Transformation Roadmap and the Autonomous Systems Project and UTM

Unmanned air vehicles (UAV) and personnel air vehicles are expected to grow from today's nascent industry to a $20B business within 20 years. The NASA UTM project has made significant strides in demonstrating how an appropriate automated air traffic management system could enable this UAV growth and make the US a leader through technology experimentation in the UTM project. In addition, automation, in particular autonomous air vehicles in a UTM like air traffic management system has the long term ability to enable the National Aerospace System to increase capacity and safety. Given the importance of this area to the US and NASA, the Committee recommends that the UTM project be expanded and accelerated. In addition, the committee recommends that the new Autonomous Systems project include a focus on autonomous air vehicles and address the gaps not being funded by industry like autonomous verification and validation.

2016 Work Plan – All Items Completed Except Two

NAC Aero Committee Work Plan

1. Review the ARMD ten year investment strategy and discuss changes based on the FY17 President's budget. (March)
2. Review the overall Thrust roadmaps and provide feedback. (March, November)
3. Review the NASA – USAF collaboration efforts through the context of the Executive Research Committee (ERC). (March)
4. Review the Hypersonic research strategy at the $25M a year funding level and provide feedback on the technical content and partnering approach. (March)
5. Provide feedback on the NRC Low Carbon (Thrust 4) study and provide recommendations on how this report should influence the ARMD portfolio. (July)
6. Review the New Aviation Horizons formulation plan including the Low Boom Flight Demonstrator planning. Focus is on having a conversation about context and principles related to the planning for the flight demonstrators. The Committee will provide experiences, thoughts and recommendations about flight demonstrators. (July)
7. **Review the ARMD integrated strategy for UAS (including UTM) research.** (November) – **Moving to 2017 Work Plan**
8. Review the formulation and execution activities of both the **Advanced Composites (Moving to 2017 Work Plan**) and the System-wide Safety Assurance projects. (November)
9. Review ARMD autonomy research strategy. (November)
10. Review CFD Vision 2030 implementation plan and synergy with the new funding model for key facilities to maintain aeroscience technical capability. (November)

BACKUP

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Research and Technology Thrusts

T1 — **Safe, Efficient Growth in Global Operations**

- Enable full NextGen and develop technologies to substantially
- reduce aircraft safety risks

T2 — **Innovation in Commercial Supersonic Aircraft**

- Achieve a low-boom standard

T3A ST — **Ultra-Efficient Commercial Vehicles**

- Pioneer technologies for big leaps in efficiency and environmental performance

T4 — **Transition to Low-Carbon Propulsion**

- Characterize drop-in alternative fuels and pioneer
- low-carbon propulsion technology

T5 — **Real-Time System-Wide Safety Assurance**

- Develop an integrated prototype of a real-time safety monitoring and assurance system

T6 — **Assured Autonomy for Aviation Transformation**

- Develop high impact aviation autonomy applications